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November 18, 2002

Riaz Shaikh
Supervising Engineer
New Jersey Board of Public Utilities
Division of Energy
Two Gateway Center
Newark, NJ 07102

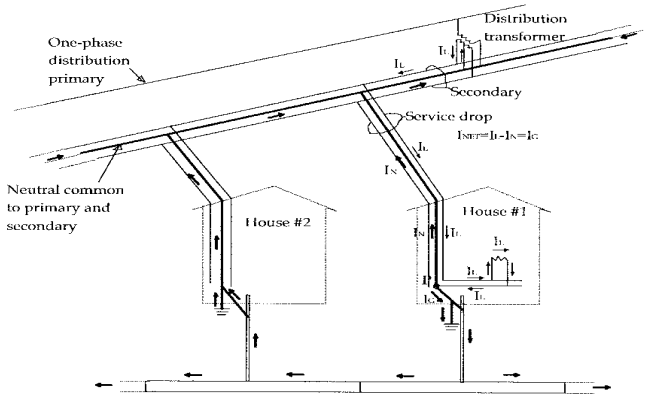
Subject: Brief Summary – *New Jersey Stray Voltage/Ground Current Investigation & Final Assessment* dated November 4, 2002

Dear Mr. Shaikh:

The following is a brief summary of the *New Jersey Stray Voltage/Ground Current Investigation & Final Assessment* dated November 4, 2002:

Perceived Stray Voltage Events & Causes

In July 2002 during the peak summer load and *exceptional drought* conditions several JCP& L customers adjacent to the Herbertsville Substation on Driscol and Frede Drives in the Town of Brick, New Jersey, reported *tingling sensations* known as *stray voltage* while touching their pools, Jacuzzis, outdoor showers and other conductive objects. Testing revealed the problem still persisted with the main electrical panels de-energized (breakers or fuses open) indicating the stray currents (the cause of stray voltages) appeared to enter each residence from the utility pole via the overhead secondary service neutral conductor, which is bonded to the neutral-ground bus in each main electrical panel. Also grounded to the neutral-ground bus are the metallic water service pipe, ground rod, CATV and telephone drops (see diagram below for pictorial representation).



Ground Currents Caused by Residential Loads in a Typical Situation

On the utility poles the overhead secondary service neutrals are bonded to the primary neutrals, down-grounds and ground rods, CATV and telephone cable guy wires. Under normal seasonal conditions with ample rain and low soil resistivity, the primary neutral currents (known as zero-sequence currents because of the unbalanced phasing) return to the substation via the overhead primary neutral conductors and underground earth channels (composed of conductive layers of soil). Normally, earth channels return a significant portion of the primary neutral currents, which enter the underground earth channels from the pole down-ground rods, and metallic water service laterals/mains that meander under the front yards, sidewalks and streets.

The Herbertsville substation and adjacent neighborhoods "showed uniform geology in the area of concern….fine to coarse quartz sand with quartz-pebble" according to the NJGS. Since sandy soil normally has high resistivity, during the 2002 drought, the existing earth channels quickly disappeared as the water table (saturation zone) retreated forcing significantly more primary neutral current to return to the substation via the overhead primary neutrals. This additional primary return current increased the voltage potential (difference) between the substation ground (now electrically isolated from the adjacent neighborhoods due to the exceptional drought and sandy conditions) and the multi-grounded primary neutral (MGN) distribution systems in the adjacent neighborhoods. The consequence was an increase in neutral-to-earth voltages (NEV) on the pole down-grounds and grounded-neutrals in the main electrical panels within homes near and adjacent to the Herbertsville substation.

JCP&L Response

Measured 5-10 Volts of neutral-to-earth voltage (NEV) on the utility pole down-grounds on Driscol and Frede Drives -- initiated *standard troubleshooting procedures* until magnitude of problem identified. Immediately responded with a *vigorous mitigation program* to install 7,000 feet of 2/0 primary neutral wire with additional down-grounds/rods, re-crimp all transformer down-ground connections, and add three 40-ft ground rods at the ends of Lines 82 and 83 that reduced the neutral-to-earth voltages (NEV) on Driscol, Spiral and McArthur Drives by 50% from 10 V to 5 V.

VitaTech's Final Assessment & Recommendations

After performing a thorough site survey and assessment of the recorded data (neutral-to-earth voltages, earth-to-earth voltages, net pole/phase currents, ground and primary neutral currents, magnetic harmonics and magnetic flux density emissions), the following three issues contribute to the stray current (i.e., stray voltage) problems at the Herbertsville substation and four distribution lines 80, 81, 82 and 83:

1. Primary neutrals on Lines 80, 81, 82 and 83 not sized to accommodate soil and exceptional Summer 2002 drought conditions.
2. Poor soil conditions and low water table (saturation zone) at the Herbertsville substation and four distribution areas – impedes earth return currents traveling back to substation. Soil resistivity increased by a factor of 2-3 during the summer of 2002 drought: soil resistivity during normal summers with adequate rain probably ranged from 600 – 1200 ohm-meters, then increased to 2,000 to 3,000 ohm-meters, if not higher, during drought.
3. Unbalanced phases exceeding 10% on Lines 80, 81, 82 and 83 during average load conditions -- could approach 20-25% during summer peak loads.

VitaTech recommends the following to mitigate the "stray voltage" problem in the Brick neighborhood and Herbertsville Substation:

1. Oversize primary neutrals on Lines 80, 81, 82 and 83 as specified in *Figure #12, Recommended Upgrade To Primary Neutrals* to match the size and impedance of the 397AA phase conductors. A total of 37,600 feet (7.12 miles) of upgraded 397AA primary neutrals are recommended to mitigate the stray voltage problem and achieve a neutral-to-earth voltage of 4-5 volts during summer months on the substation grid and down-grounds of the adjacent neighborhoods during peak summer loads. Specific routes and circuit length details for the recommended upgraded primary neutrals are provided in Figure #12; however, selected lateral circuits may also require upgraded 397AA neutrals to achieve the 4-5 volt summer performance objective including: Azalea Drive, Truman Drive, Harding Drive, Roosevelt Drive and Old Squan Drive.
2. No additional ground rods, mats or plates are recommended for the substation ground grid; however, the substation ground plane should be expanded to the extents of the new fence line with additional grounds bonded from the grid to the fence, where needed. (Note: this will have no adverse effect on stray voltage.)
3. Balance the phases on Lines 80, 81, 82 and 83 to within 10% (as measured by the SCADA equipment at the substation) during average loads (20-25%) and no more than 15% during peak summer loads to minimize zero-sequence currents.

Best Regards,

Louis S. Vitale
President & Chief Engineer
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